It is gratifying, too, to think that, so far at least as the scientific world is concerned, his great services were adequately recognized and honored during his lifetime.

September, 1909.

THE RETURN OF HALLEY'S COMET.

By W. W. Campbell.

A celestial event of unusual interest is expected soon—the return of Halley's Comet. Its appearance will be welcomed as the coming of a faithful friend, whose visits to the Sun's domains have repeated themselves once every seventy-seven years since long before the time of Christ. Any day may bring the news that this object has been re-discovered, near the northern edge of the constellation *Orion;* but we are really not expecting the announcement until the last third of 1909. The comet will be faint when first seen, for we know quite closely where to look, and the most powerful photographic telescopes in several countries are periodically "prospecting" the critical region.

Why is this comet known as Halley's? The incidents connected with its christening form an interesting chapter in the early history of astronomy. A brilliant comet appeared in 1682, when Halley was a young man, in England. This was Halley's Comet, but his name was not connected with it until much later, as we shall explain. Halley's friend, the great Sir Isaac Newton, had but recently (about 1670-80) discovered the law of gravitation, and had proved that a comet or other body completely subject to the Sun's attraction must move in an ellipse around the Sun. Newton was of a retiring disposition and took no steps to make known his immortal discoveries. Halley, on the contrary, was a man of action. These characteristics of the two men are apparent from their portraits. The manuscript copy of Newton's *Principia* was entrusted to Halley, and the latter, in the absence of other funds available for the purpose, published the book in 1686, at his own expense, though he was a man of small financial

EDMUND HALLEY.

means. This act alone stamps HALLEY as worthy of our homage.

HALLEY realized the wonderful import of The Great Law, certainly as early as 1685, but his opportunity for systematic work in astronomy did not come until 1704, when he was appointed professor of geometry at Oxford. He immediately began the study of comets, basing his studies upon NEWTON'S law. He became the first great calculator of comet orbits. In a little more than a year he had twenty-four to his credit; orbits of all the comets, in fact, for which he could find accurate observations. This meant prodigious labor, in those days, for the good observations and the highly developed methods of our time were unknown. He found that three comets out of the twenty-four had traveled from distant space, around the Sun, and out into distant space, *along the same path,* whereas the other twenty-one had each a different path. Were these three comets one and the same body? If so, their common orbit must be an ellipse. The crude observations of the sixteenth and seventeenth centuries did not permit him to decide whether the orbit was a long ellipse or a parabola (a curve extending out to an infinitely great distance). If the latter, the three comets would have traveled away from our solar system never to return. If they were the same body, they should have returned at about equal intervals of time; and this is what did occur, for the dates when the three comets had been nearest to the Sun were—

1531	August 24	
		Interval, 76.2 years
1607	October 16	
		Interval, 74.9 years
1682	September 4	

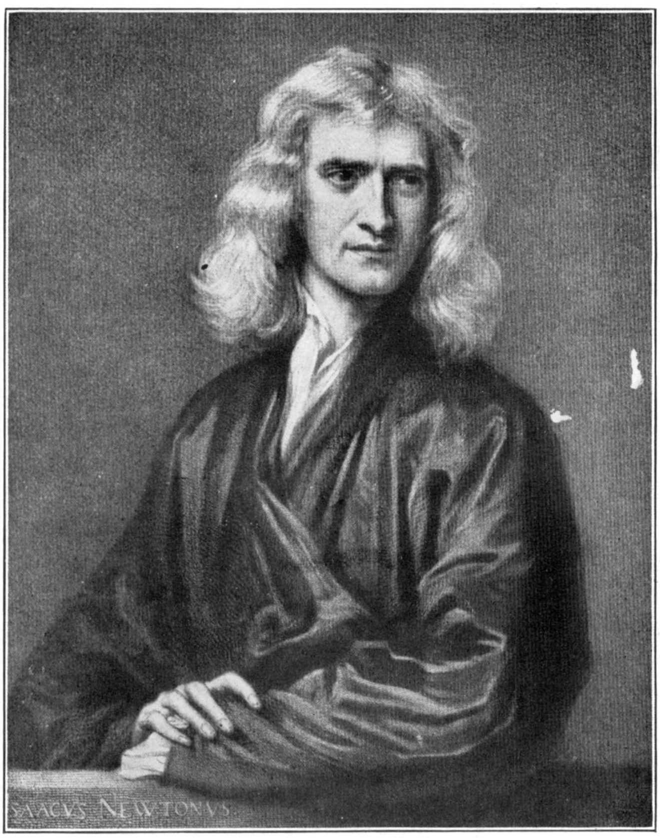
The small inequality of intervals he correctly attributed to the disturbing attractions of the planets *Jupiter and Saturn.* He predicted that the great comet would complete another revolution in its orbit in seventy-five or seventy-six years and reappear about 1758. He said that he could not predict the time more accurately, for the effects of *Jupiter's* and *Saturn's* disturbing attractions were not yet computed. HALLEY (born 1656, died 1742) knew that he would not live to witness the return, but he confidently and patriotically called upon posterity to remember that this prediction had been made by an Englishman,—*"ab homine Anglo."*

The comet did return, in March, 1759. It was a little later than expected because of the disturbing attractions of the planets *Uranus* and *Neptune,* which had not yet been discovered, and whose influence upon the comet's orbit, therefore, could not be taken into account. This was indeed a great triumph in exact science, made possible by NEWTON's overwhelming genius and HALLEY's vigor. It is easy to predict the returns of comets in the twentieth century, but this is so because NEWTON and HALLEY lived and labored as pioneers.

Halley's Comet reappeared in 1835, within a few days of the predicted time. It is due to be again "in perihelion," *i. e.,* nearest to the Sun, in the first half of April, 1910. The comet, though invisible, is at present (April, 1909) much closer to us than *Jupiter* is, and slowly drawing nearer to the Sun. When we may expect to see it without telescopic assistance and how bright it will be at maximum are too uncertain for prediction. Certainly for a few months in the first half of 1910 it should be a conspicuous object. Comets brighten and develop their tails as they approach the Sun, reaching their greatest development when in or near perihelion. For this reason it is their unfortunate practice to disappear from view, in the Sun's glare, just when they are largest; and Halley's Comet will be out of sight for a few days while it is passing on the other side of the Sun, probably in March, 1910. We should see it at its best just after perihelion passage.

The history of this most famous of comets prior to HALLEY's first date, 1531, has been traced by three able English astronomers, HIND, COWELL, and CROMMELIN, as far back as B. C. 240. In all, twenty-nine appearances recorded in history have been identified. These have occurred at average intervals of seventy-six and three-quarters years. The individual values of the intervals have varied between seventy-four and a half and seventy-nine years, according as the disturbing actions of the planets combined to shorten or to lengthen the period.

There are extant several quaint pictorial representations at many of its early returns. An especially interesting one, though of minimum scientific value, is for the return in 1066,—the year of William the Conqueror's invasion,—as preserved in the famous Bayeux Tapestry. Sir JOHN HERSCHEL's drawing is probably our best record of its appearance at the 1835



Sir Isaac Newton.

Halley's Comet in 1066, on the Bayeux Tapestry.

return. Fortunately we now have photography to make permanent records of both its general and its detailed structure. The dry-plate puts down details which the eye cannot see, and it does the work with great accuracy. Since BARNARD's pioneer success in the photography of comets at the Lick Observatory, about 1890, no one seriously attempts to "draw" a comet. An inspection of the two photographs of Comet MOREHOUSE, just visible to the naked eye in the fall of 1908, will show the richness of structural detail, none of which could be seen in any existing telescope.

The long elliptical orbit of Halley's Comet and the nearly circular orbits of the Earth, *Mars, Jupiter, Saturn, Uranus,* and *Neptune* are represented in the figure—approximately to the correct scale; but it should be said that the plane of the comet's orbit makes an angle of 18° with the Earth's orbit plane. The comet's orbit therefore passes "through" the planetary orbits like the two adjacent links of a chain. The comet will approach within fifty-six million miles of the Sun, and then recede during thirty-eight years until it is far beyond *Neptune's* path. In perihelion it must travel thirty-four miles per second, but at the outer turning its speed will be less than one mile a second.

For purposes of description, it has been found convenient to divide the structure of a comet into three parts, as follows:—

1. The densest and brightest part near the center of the head, called the *nucleus.* Nearly all the mass of a typical comet resides in the nucleus.

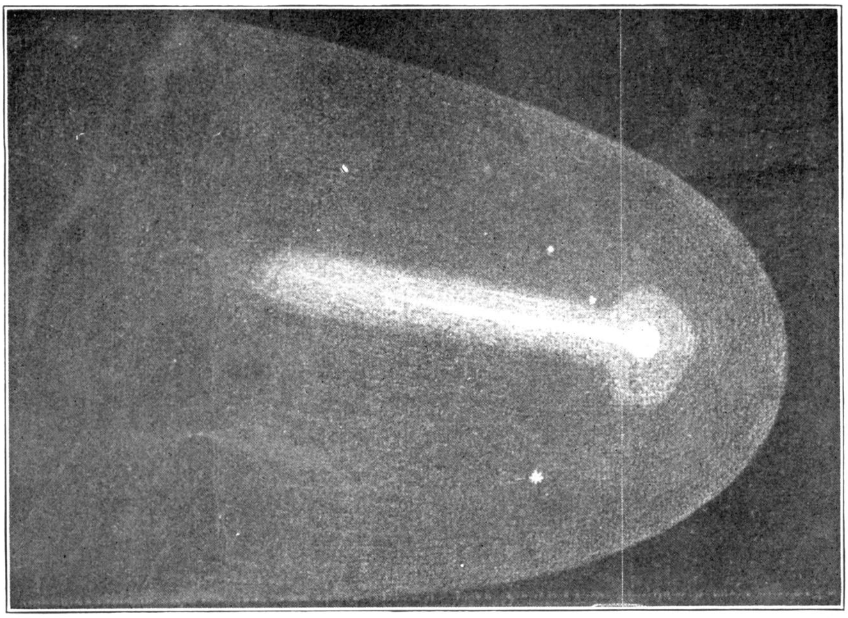
2. The *coma,* or envelope of low density surrounding the nucleus. In occasional comets the head consists entirely of coma without an apparent nucleus.

3. The *tail,* which always points approximately away from the Sun. When the comet is traveling toward the Sun the tail follows the head; when the comet is going away from the Sun, the tail precedes the head. This is illustrated in the drawing of the comet's orbit.

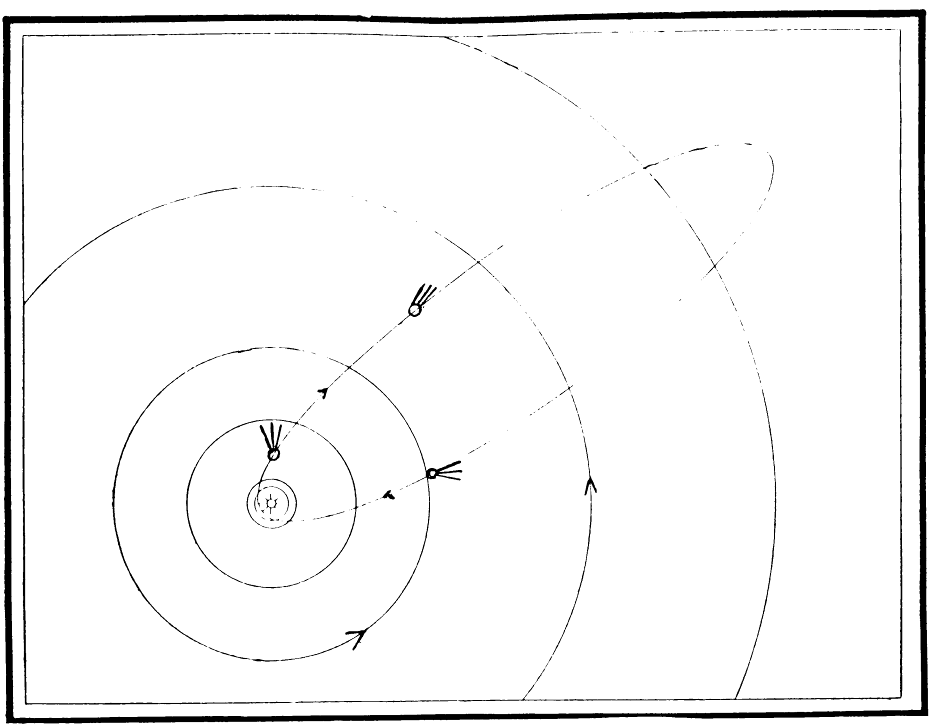
The fact that a comet's tail always points away from the Sun was early recognized. There could be no doubt that some force originating in the Sun was repellant to the materials composing the tail; but to determine the nature of this force defied us for generations.

Since the coming of photography and the accurate recording of details of comet structure utterly invisible to the eye, it has been possible to measure these motions. Comparisons of photographs of the same comet made two or three hours apart have shown that condensations and other structural forms have moved rapidly outward during the interval; only a few miles per second at first, but faster and faster as the distance out in the tail increased. Some observed speeds have been nearly fifty miles per second. Fifty miles per second is more than four million miles per day. If such motions exist, the constituents of the tail on one night are not the constituents of the tail of the following nights. Photographs of many comets taken on certain nights seem to bear no resemblance to those taken on the preceding or following night. The tails of the earlier dates have been driven off into space, scattered into invisibility, and entirely new tails have taken their places. The forces acting outwardly from the Sun and responsible for these expulsions were mysterious, and it is only within the last ten years that a fairly satisfactory theory has been established. Half a century ago the great physicist, CLERK-MAXWELL, in developing the electro-magnetic theory of light, deduced mathematically that the so-called light- and heat-waves, in striking upon any object, exert a pressure upon that object, very much as ocean waves falling upon the cliffs press against the obstructing rocks. The pressure due to light- and heat-waves, called radiation pressure, is extremely slight; so slight, in fact, that skilled experimenters were unable to detect its existence for many years. At last, about the year 1900, a Russian physicist, LEBEDEW, was able to observe this effect; and a few months later two American physicists, NICHOLS and HULL, were even more successful, for their accurate observations showed a satisfactory agreement with the demands of MAXWELL's theory.

Almost immediately the famous Swedish scientist, ARRHENIUS, expressed his belief that in this pressure of the Sun's heat- and light-waves we have the force which forms comets' tails. All the materials of a comet are necessarily attracted by the Sun, according to the law of gravitation. There can be no doubt that they are also acted upon by radiation pressure. The former seeks to draw all into the Sun, the latter to



Halley's Comet in 1835.
(By Sir John Herschel.)



Orbits of the Planets and the Comet.
(The smallest circle is the Earth's orbit.)

drive them into outer space. These are opposing forces. On the more massive parts of a comet, comprising the nucleus, radiation pressure is ineffective; and the nucleus moves along in its prescribed curve with remarkable precision. Not so with the finely divided materials of the coma and tail. Gravity acts as a function of a particle's mass, whereas radiation pressure's action is dependent upon the surface-area of a particle in relation to its mass. As particles become smaller and smaller a size will be reached such that these opposing forces will be precisely balanced. Particles larger than these will be drawn nearer to the Sun. Particles smaller will recede from the Sun.

What seems to take place in a comet is something like this: Minute particles of solid matter or molecules of gas are expelled from the nucleus chiefly on the side toward the Sun, probably under the influence of the Sun's heat. Radiation pressure acts upon these particles to turn them directly away from the Sun; and the cloud of particles thus projected forms the tail. As the repellant forces act continuously, the particles must travel continuously faster; and this is the observed fact. Smaller and less dense particles must travel more rapidly than the larger and denser ones.

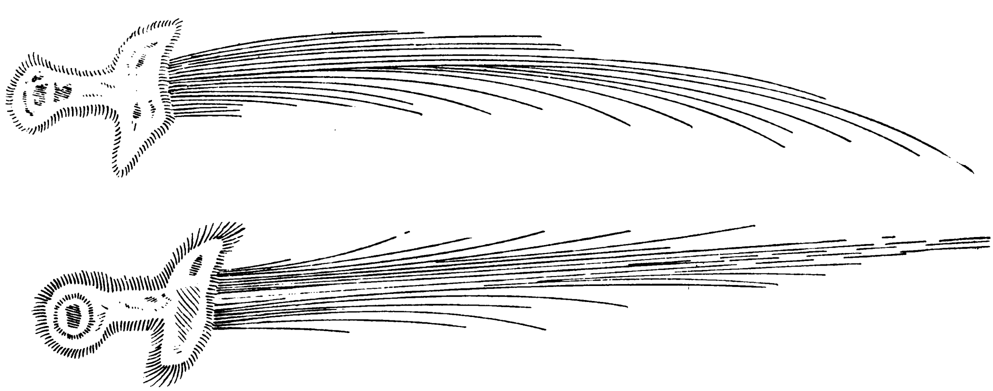
The constant expulsion of matter along the tail into outer space must of necessity cause a comet to grow smaller. Disintegration is continuous, and the tail at any moment is made up of materials lost forever from the nucleus. Several faint comets moving around the Sun in small orbits have been observed to be fainter at each successive return. Some have even disappeared entirely. Two such comets, now lost to view, reveal themselves only by virtue of meteor showers about the middle of August and the middle of November: the matter composing their nuclei has been scattered along their orbits, and the annual passing of the Earth across these orbits leads to collisions between the cometary fragments and our higher atmosphere. There is no reason to doubt that Halley's Comet is slowly disintegrating, and, after long ages, will suffer some such fate.

Our knowledge of the chemical composition of comets and of the state in which cometary matter exists is meager and unsatisfactory. A few give spectra very like that of our own Sun, indicating that they are shining by reflected sunlight, as the

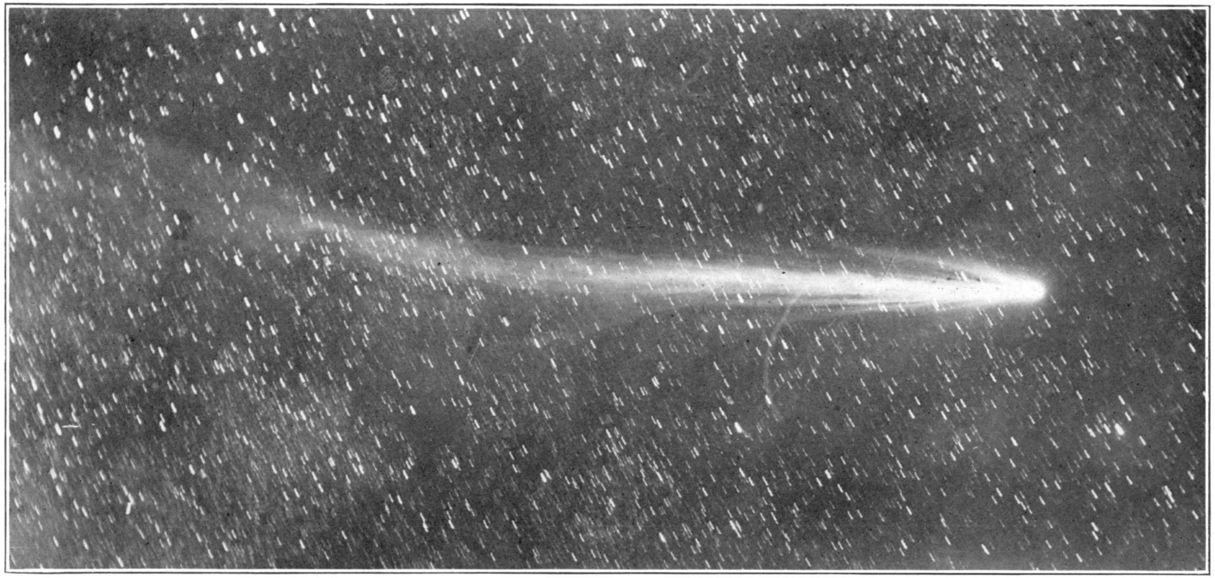
planets shine. Other comets send out their own light, almost exclusively, the radiations coming chiefly from carbon and cyanogen sources. Still others have mixed spectra, showing both inherent light and reflected light. Why comets shine by virtue of light within themselves is a mystery, for it is difficult to conceive that such attenuated bodies should have the heat of incandescence throughout their mass. Although many comets have volumes thousands of times as great as the Sun's volume, their total mass is insignificant even in comparison with that of the Earth; and such mass as they have is nearly all in the nucleus. The tails are surely less dense than the most perfect vacuum we can produce in the laboratory.

Halley's Comet is due to pass near the Earth in May, 1910,—perhaps within 10,000,000 miles of us. Let no one draw the inference that there may be a dangerous collision with the Earth, for such is not the case. Their paths are too widely separated. Even if the path of the comet were entirely unknown, we could say that the chance of a collision with the denser nucleus is so small as not to call for consideration. And if we should pass through the tail, there would be no evidence of such an encounter, unless it consist of a harmless meteor shower, for the tails of comets are certainly composed of exceedingly minute and widely scattered particles.

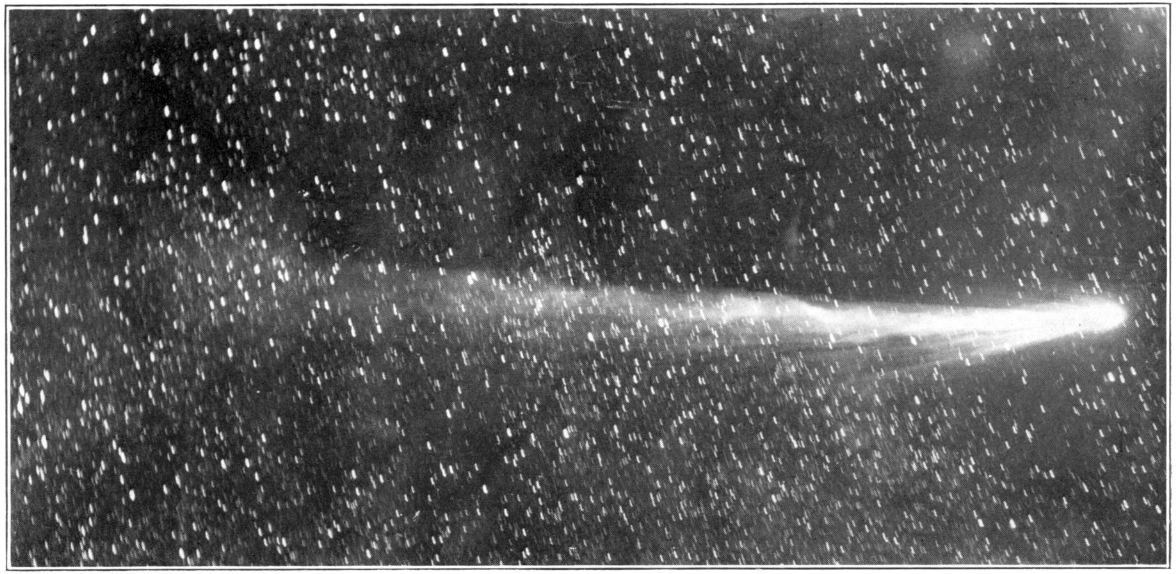
The ancients thought of comets as hairy objects, from the appearance of the tails; hence the origin of the term "comet," from the Greek *kometes,* signifying "long-haired." This belief prevailed certainly up to HALLEY's day and generation.



REPRESENTATIONS OF COMETS AS FLAMING SWORDS.



Comet Morehouse, Photographed at Lick Observatory, November 15, 1908.



Comet Morehouse, Photographed at Lick Observatory, November 18, 1908.

All sorts of fantastic and fearsome ideas have attached to comets, from early historical times to near the close of the nineteenth century. The writer remembers clearly that his neighbors of thirty years ago considered comets to be messengers of disaster. The greatest comet of the nineteenth century, DONATI'S of 1858, was the accredited forerunner of our Civil War. Medieval representations of comets as flaming swords were common.

In HOMER'S "Iliad" XIX, 381, we read:—

> "Like the red star, that from his flaming hair
> Shakes down disease, pestilence and war."

From EVELYN'S Diary of 1624:—

> " . . . the effect of that comet, 1618, still working in the prodigious revolutions now beginning in Europe, especially in Germany."

From MILTON'S "Paradise Lost," II, 708-711:—

> " . . . and like a comet burn'd,
> That fires the length of Ophiuchus huge
> In th' Arctic sky, and from his horrid hair
> Shakes pestilence and war."

Not the least of the services of science to civilization has been the gradual emancipation of humanity from all fear of comets.

Astronomers will welcome the coming of Halley's Comet, full of hope that the photo-dry-plate, the spectroscope, and other ways and means of attack invented since its last visit in 1835 will enable them to remove something of the mystery of comets, the most mysterious of all celestial bodies.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1909.

By MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter..	Nov. 4, $1^h 38^m$ P.M.	Last Quarter..	Dec. 4, $8^h 12^m$ A.M.
Full Moon ...	" 12, 6 18 P.M.	Full Moon ...	" 12, 11 59 A.M.
First Quarter..	" 20, 9 29 A.M.	First Quarter..	" 19, 6 18 P.M.
New Moon ...	" 27, 12 51 A.M.	New Moon ...	" 26, 1 30 P.M.

There will be a total eclipse of the Moon on the night of November 26th-27th. The entire eclipse will be visible through-